

Description of Analytical Tools

Name: Probabilistic Climate Projections for California

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Availability of Technical Support: A website, reference papers, and technical support will be available.

Analytical Tool Category: Climate, hydrology.

Main Features and Capabilities:

- The climate scenarios will have a statewide scope
- The temporal scale will be from the present to the end of this century
- The time steps will be daily but monthly averages will also be generated
- The climate projections will have adequate temporal and geographical resolution to allow for meaningful climate change mitigation and impact analyses.

Applications: PIER funded research has generated climate projections using the outputs of two global general circulation models. These scenarios were used to estimate potential impacts of climate change on water resources using the CALVIN model. The same scenarios can be used with other water system models such as CALSIM. In this preliminary study, the researchers assumed that all projections were equally probable. One scenario suggested substantial increases in precipitation levels while the other estimated a small reduction of precipitation from historical conditions. These widely divergent scenarios hamper somewhat the development of meaningful policy initiatives to deal with climate change. To deal with this issue, PIER is developing probabilistic climate scenarios to be used for both research and state planning efforts.

Calibration/Validation/Sensitivity Analysis: The regional climate models (RCM) used to generate the climate projections adequately reproduce historical climate conditions. These models are driven by outputs from global circulation climate models that due to their coarse geographical resolution cannot be used directly for regional (California scale) impacts and adaptation analyses. The global models, however, adequately reproduce large-scale atmospheric features. RCMs are used to downscale the outputs of global circulation models to a specific region. PIER is using the outputs from several global circulation models and a few RCMs to develop probabilistic climate projections for California.

PIER is also coordinating some RCMs sensitivity studies to estimate how several factors affect climate and hydrological conditions in California. For example, a PIER researcher,

Prof. Mark Jacobson, used a climate model to estimate the potential effect of air pollution on climate and precipitation in the State. His results suggest that aerosols have a significant effect on solar radiation, surface temperature, and precipitation levels. Under a different PIER research project, a group of researchers are further investigating the role of aerosols on precipitation at high elevations. PIER is also coordinating a sensitivity study with several regional climate modelers trying to estimate the importance of agricultural irrigation and urbanization in California's climate. The results of the sensitivity analyses will be used to inform the development of the numerical and statistical simulations that will result in climate projections for California from the present to the end of this century.

Peer Review: Previous PIER funded studies in this area have been published and peer reviewed. The climate projections for California will result in several peer-reviewed publications in technical journals. Several papers documenting the global and regional climate models are available in the peer-reviewed literature. A PIER report fully documenting the development of the climate scenarios will also be available.

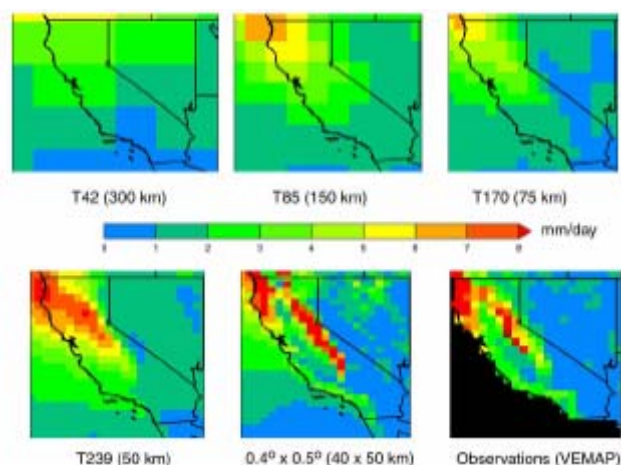
Anatomy of the GCMs and RCMs:

-Conceptual Basis: Global coupled Atmosphere-Ocean General Circulation Models (GCMs) currently used for projecting future climate have a grid box size of 100–200 km. Many of these models are able to simulate present-day climate well on spatial scales of 1000 km upwards, and the best models provide reasonable representations of the climate on somewhat smaller scales. Their grid-box resolution, however, cannot capture regional orographic details nor resolve important cyclonic disturbances or similar-sized circulation features. This precludes an accurate representation of the climate on scales of individual grid boxes. For many impact models, however, information is required on sub-grid scales of 10 to 100 km (referred to here as the local to regional scale). The method for producing local-to-regional scale information from larger-scale GCM data is called downscaling.

Two downscaling methods are commonly used, dynamical and statistical downscaling. Dynamical downscaling methods include: the use of a limited-area, high-resolution Regional Climate Model (RCM) nested within and driven by time-dependent lateral and lower boundary conditions from a GCM; the use of a global model with variable spatial resolution (a stretched-grid atmospheric GCM); or the use of a high-resolution atmospheric GCM in time-slice experiments driven by Atmospheric-Ocean GCM forcing factors and surface boundary conditions. There are two types of RCM based downscaling, depending on whether the RCM results feed back to the driver GCM (two-way nesting) or not (one-way nesting). Statistical downscaling involves the derivation, validation, and application of a statistical model (usually based on regression analysis) that relates local/regional-scale climate variables to global-scale predictors. PIER is using both numerical and statistical downscaling techniques but only one-way nesting of numerical regional climate models will be pursued.

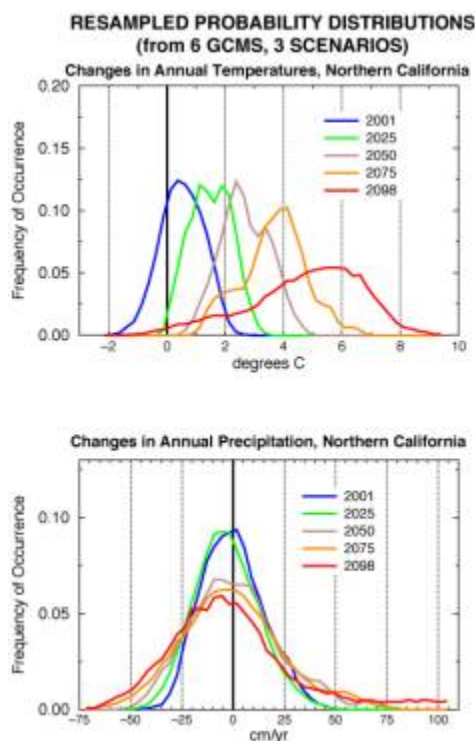
Theoretical Basis: GCMs simulate the law of motion, based on conservation of mass and energy, in a quest to estimate potential changes in climate given external forcing factors such as the increased atmospheric concentration of greenhouse gases. However, these models require the use of several simplifying assumptions due to lack of scientific knowledge or lack of computer resources to solve all physical processes at all the spatial and temporal scales. Numerical RCMs or limited area models also numerically solve the equations of motion (conservation of mass and energy) and are in some respect very similar to the global models. Several numerical experiments have confirmed that the use of RCM models driven by the output of global models can adequately reproduce the main features of regional climate.

The figure below presents the results of a model using several levels of geographical resolution. The T42 case (300Km) resolution is a typical result of what can be expected from global circulation models. The modeling results are quite different from regional scale observations (lower right figure). The regional model at 40 x 50 km resolution more closely reproduced the observations. PIER is developing climate scenarios at a 10 km resolution that will improve the resolution of the scenarios while providing the outputs needed for detailed climate impacts and adaptation analyses.



PIER Report by Dr. Tom Wigley, 2004. Graph generated by Dr. Phil Duffy at LLNL

Under funding from PIER, researchers at the Scripps Institute of Oceanography are developing a technique to allow the use of multiple climate projections using a variety of regional models. The approach consists of a sophisticated statistical re-sampling of the outputs to generate probabilistic climate projections. The graph below shows a proof-of-concept analysis using the outputs of global models with the estimated changes in average temperature and precipitation for Northern California.



PIER Report by Dr. Mike Dettinger, 2004

Numerical Basis: The global and regional dynamic models solve the basic equations of motion; conservation of mass and energy, using numerical integration schemes. This is done for a three dimensional mesh of grid points at different horizontal and vertical resolutions. Some features (e.g., cloud formation) are parameterized (simple or semi-empirical mathematical representation of certain processes) to be able to obtain numerical solutions with existing computer resources.

Statistical downscaling consists of the development of mathematical relationships or correlations between large scale features of climate (e.g., geopotential heights) estimated by numerical GCMs and climate conditions at given grid points in the region of study. An example of this technique is the canonical correlation method being enhanced by PIER researchers at Scripps.

Input and Output: The inputs needed for the global circulation models are the boundary conditions for the atmosphere and the oceans, initial conditions to start the simulations, and a description of how important features would change with time (e.g., atmospheric carbon dioxide concentrations). The regional climate models require the same type of information but only for the specific region being modeled. In addition, the regional models require the use of outputs from the global models at the boundaries of the modeling domain.

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The outputs from the global and regional models are the estimated changes of temperature, precipitation, and other meteorological variables.

Data Management: PIER researchers will be in charge of the data management for this project. All the outputs generated by this project, however, will be available to public agencies and to the research community using different means such as the Internet.

Software: The outputs generated by this project will be available in common ASCII formatted files and in any other format required by state agencies and the research community. PIER does not envision the need for special software for data manipulation.